New Trends of High-Performance Polymers Towards Emergent Advanced Applications

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Abstract

This article describes the recent development of high-performance polymers (HPPs)-based advanced materials for various optoelectronic applications, such as electrochromic (EC), electrofluorochromic (EFC), and polymeric memory devices. We herein systemically discuss the structural design, optical and electrical properties of different triphenylamine (TPA)-containing HPPs that will be beneficial for polymer chemists and scientific community to have deeper and broader understanding of the recent developments and further prompt the engineering and conceptual design of materials for the emerging applications (data storage, displays, and flexible electronics). Thus, some of the recent works in our laboratory involving the synthesis and properties evaluation of functional HPPs as well as their structural design by using the respective TPA-containing monomers will be included in this talk. Solution-processable functional HPPs were successfully prepared as the application of AIE-based PL polyimides and EC materials with interesting color transitions and good EC reversibility in the visible region or NIR range and EFC (so called electrochemically photo-switching) devices. The relation between structures and properties of the resulted functional HPPs will be presented in terms of their functionality.

Introduction

TPA-based EC HPPs have attracted increasing attention due to their promising optical and electrical properties that make them with great potential for practical applications. Moreover, the recent development of EC devices derived from HPPs, including the structural design, synthesis, and characteristic evaluation have also been discussed and summarized. Based on the excellent and interesting results of these HPP-derived EC devices, we believe that the optimization could further improve device performance and fully explore the potential of these multicolored EC devices for wearable applications, smart windows in building construction, shutters of aircraft, sunroof and auto-dimming rearview mirror for automobiles, electronic tag and displays. EFC that deals with the electrically driven reversible optical changes of fluorescence has only recently been coined. Research is at a relative early state compared to fields in electrochemical manipulation of optical properties such as EC (redox-switchable color) or electrochemical light generation by electrochemiluminescence. EFC devices containing materials whose fluorescence can be switched by external stimuli have attracted for many applications.

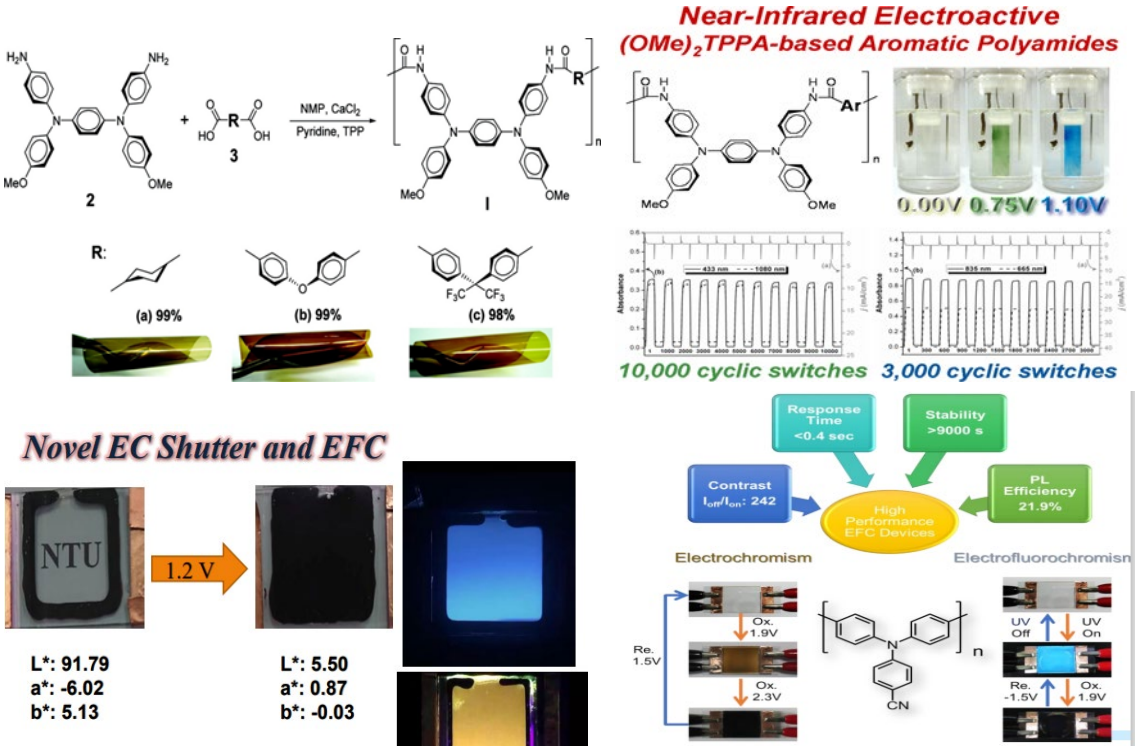
The development of polymers for use in solution processable fabrication of high mechanical strength, low cost, and high-density data storage memory devices is an emerging area. HPPs are the most attractive materials for memory applications when considering the critical issue of heat resistance during the device fabrication process and operation due to their high thermal/dimensional stability and mechanical strength. Nearly the current level of memory performances, may be reproduced by carefully considering the structural design based on the systematically investigated switching mechanisms. The extremely high endurance during long-

term operation makes HPP a very promising material for memory applications.

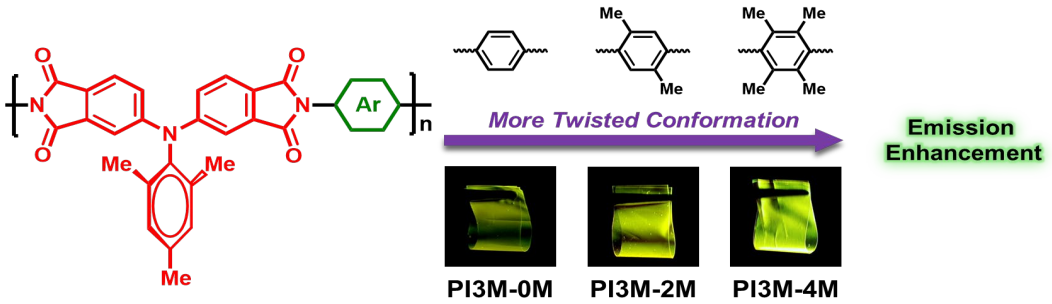
Experimental and Results

A series of triarylamine-based HPPs was designed and prepared to investigate the effect of molecular design on the performance of specific functional behaviors.

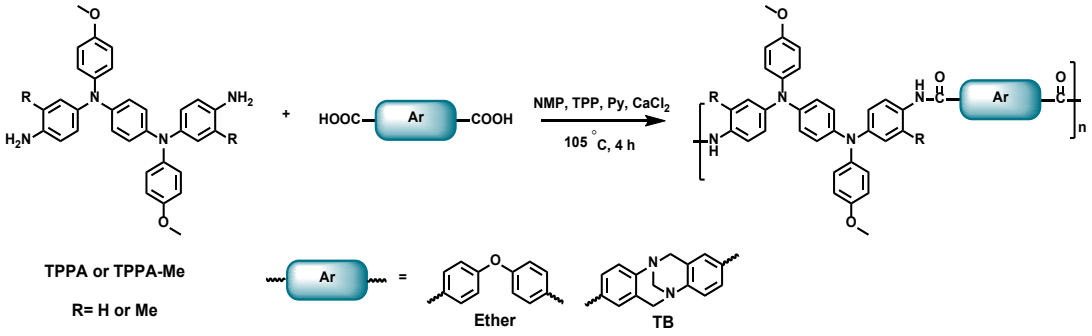
Design and Preparation of EC and EFC Polyamides with Long-term Stability for the Requirements of Practical Applications: (*Prog. Polym. Sci.*, 2019, 89, 250-287)

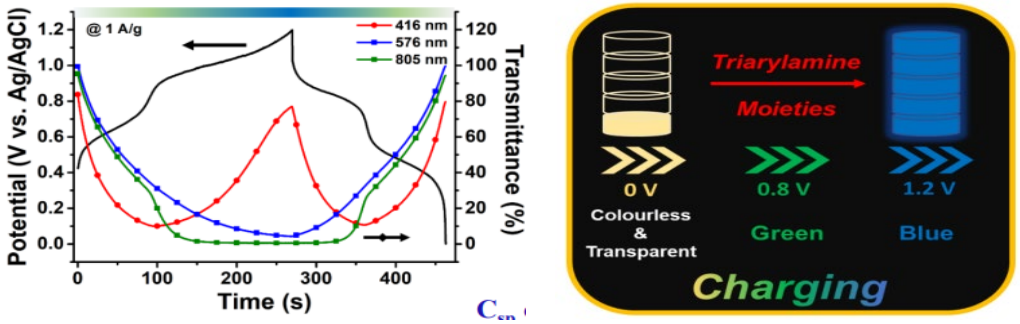


Design and synthesized of wholly aromatic polyimide film with unprecedented PL efficiency 61% and T_g 470 °C simultaneously: (*Adv. Optical. Mater.*, 2022, 10, 2101949)



Design and Preparation of Intrinsic Microporous Polyamides for Electrochromic Supercapacitor (ESC): (*J. Mater. Chem. A*, 2023, 11, 1877)





Design of AIE-active HPPs as Electrets for Energy-Saving Genuine Photonic Transistor Memory Devices: (*Adv. Funct. Mater.*, 2021. 31, 2101288; *Chem. Eng. J.*, 2023, 457,141209)

Authentic and Ultrafast Organic Photo-Recorders by AIE-Active Polymer Electrets via Interlayer Charge Recombination

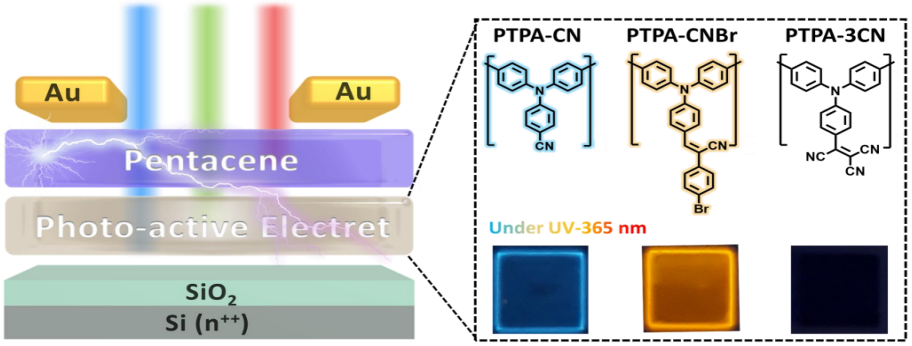
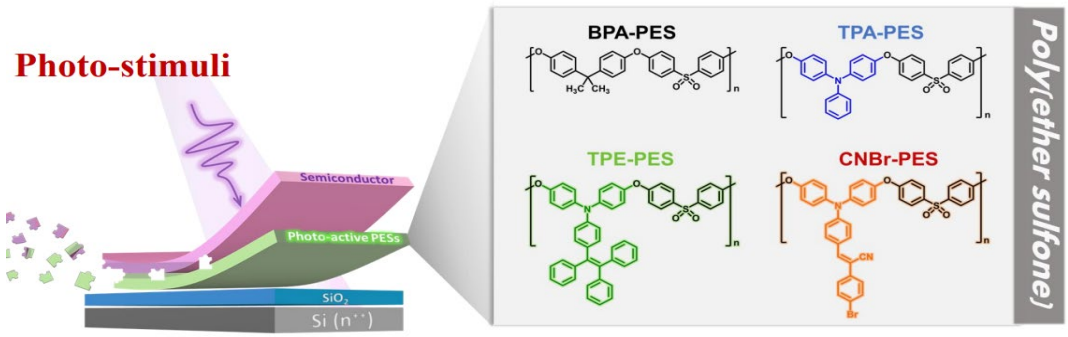


Figure Schematic illustration of the studied photo-programmable recorder device, molecular structures, and luminescence characteristics



Conclusion

In this presentation, a series of triarylamine-based HPPs was designed and prepared to investigate the effect of molecular design on the performance of electrochemical behaviors. The resulting intrinsic micropores effectively enhanced the diffusion dynamics of the counter ions within the redox-active polymer films and significantly improved the electrochromic and electrofluorochromic characteristics. In addition, this new series of polymers, triarylamine-based polyamides, revealed an intriguing discovery suitable for applying ESC materials, ascribed to the intrinsic micropores and higher specific surface area in the prepared films enhanced Csp by at least 40%. Furthermore, these redox-active polyamides exhibited two-stage distinct color changes from low voltage (0.8 V, green) to high voltage (1.2 V, blue), which are consequently helpful in monitoring the storage energy of the fabricated supercapacitors. Besides, TPA-based poly(ether sulfone)s have been elucidated soundly to construct the high-performance photonic transistor memory. The judicious design for a solution-processable charge storage layer of homopolymers could rule out the consideration of dispersion technique, specific morphology, and compromising electrical characteristics. In addition, a facile energy-efficient operation approach for genuine organic photonic memory devices has been proposed via incorporating an AIE-active group (TPE and CNBr), realizing that the photo-excitation electrons could be generated and then remain in the storage layer solely through irradiation without introducing additional electrical stress.

Reference:

[1] H. J. Yen, G. S. Liou, Design and Preparation of Triphenylamine-based Materials Towards Emergent Optoelectronic Applications. *Prog. Polym. Sci*., 2019, 89, 250-287 (Reviewer article).

[2] W. H. Chen, F. W. Li, G. S. Liou, Novel Stretchable Ambipolar Electrochromic Devices Based on Highly Transparent AgNW/PDMS Hybrid Electrodes. *Adv. Optical Mater*., 2019, 7, 1900632

[3] C. H. Chen, T. Michinobu, Y. C. Chiu, G. S. Liou, etc. Novel Photoinduced Recovery of OFET Memories Based on Ambipolar Polymer Electret for Photorecorder Application. *Adv. Funct. Mater*., 2019. 29, 1902991.

[4] Y. W. Chiu, M. H. Pai, G. S. Liou, Facile Approach of Porous Electrochromic Polyamide/ZrO_2 Film for Enhancing Redox Switching Behavior. *ACS Appl. Mater. Interfaces*, 2020, 12, 35273.

[5] C.Y. Ke, M. N. Chen, M. H. Chen, Y. C. Chiu, G. S. Liou, Novel Authentic and Ultrafast Organic Photorecorders Enhanced by AIE-Active Polymer Electrets via Interlayer Charge Recombination. *Adv. Funct. Mater.*, 2021. 31, 2101288.

[6] Y. J. Shao, G. S. Liou, Triarylamine-Based Wholly Aromatic Polyimide with Simultaneously Unprecedented Photoluminescence Efficiency and High Tg. *Adv. Optical. Mater.*, 2022, 10, 2101949.

[7] Y. J. Shao, T. C. Yen, C. C. Hu, G. S. Liou, Non-Conjugated Triarylamine-Based Intrinsic Microporous Polyamides for Electrochromic Supercapacitor: Diffusion Dynamics and Charge-Discharge Studies. *J. Mater. Chem. A,* 2023, 11, 1877.

[8] C.Y. Ke, M. N. Chen, G. S. Liou, High-Performance Aggregation-Induced Emission Active Poly(ether sulfone)s as Polymeric Electret for Energy-Saving Genuine Photonic Transistor Memory. Chem. Eng. J., 2023, 457,141209.